

AMENDMENT - Specification

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Cancel all paragraphs from page 7, line 5 to page 8, line 5 contained under the title “SUMMARY OF THE INVENTION,” of the original application. Changes made to this section are: 1) all instances of the phrase “capital goods” which are now replaced with the phrase “semiconductor substrate.” 2) change “stress/strain, and pH. In preferred embodiments, the critical parameters are related to chemical/material analysis techniques selected from the group consisting of Energy Dispersive X-ray Spectroscopy” to “stress/strain, pH, Energy Dispersive X-ray Spectroscopy”

Please insert the following new paragraphs at page 7, line 5, immediately following “SUMMARY OF THE INVENTION”.

The present invention is an apparatus for measuring critical parameters used in manufacturing of ~~capital goods~~ semiconductor substrate in microelectronic processing without evasive interruptions to manufacturing equipment. In preferred embodiments the critical parameters are selected from the group consisting of temperature, liquid and gas flow rate, distance, particles, humidity, pressure, viscosity, radiation, velocity, density, acceleration, ~~stress/strain, and pH. In preferred embodiments, the critical parameters are related to chemical/material analysis techniques selected from the group consisting of Energy Dispersive X-ray Spectroscopy~~ stress/strain, pH, Energy

Dispersive X-ray Spectroscopy (EDS), Cathodoluminescence (CL), X-ray Photoelectron Spectroscopy (XPS), Ultraviolet Photoelectron Spectroscopy (UPS), Auger, Electron Spectroscopy (AES), Reflection High Energy Electron Diffraction (REELS), X-ray Fluorescence (XRF), Photoluminescence (PL), Modulation Spectroscopy, Variable Angle Spectroscopic Ellipsometry (VASE), Fourier Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy, Solid State Nuclear Magnetic Resonance (NMR), Rutherford Backscattering Spectroscopy (RBS), Elastic Recoil Spectroscopy (ERS), Ion Scattering Spectroscopy (ISS), Residual Gas Analyzer (RGA), Dynamic/Static Secondary Ion Mass Spectroscopy, Laser Ionization Mass Spectroscopy (LIMS), Sputtered Neutral Mass Spectroscopy (SNMS), Glow Discharge Mass Spectroscopy (GDMS), Inductively Coupled Plasma Mass Spectroscopy, Inductively Coupled Plasma Optical Emission Spectroscopy, Neutron Diffraction, Neutron Reflectivity, Neutron Activation Analysis (NAA), Nuclear Reaction Analysis (NRA) and combinations thereof. In a preferred embodiment, the apparatus comprises one or more sensors, the one or more sensors attached to surfaces on the ~~capital goods~~ semiconductor substrate for collecting data therefrom. The invention also comprises an electronic device for processing data collected from the one or more sensors, and an energy source for the electronic device, wherein said sensors and electronic device reside completely on the surface of the ~~capital goods~~ semiconductor substrate. In a preferred embodiment, the electronic device comprises one or more of the following: an analog to digital converter, a signal conditioning device and a data recording device. A preferred embodiment further

comprises an external wireless receiving module wherein the collected data is transmitted digitally in real-time from the electronic device to the external wireless receiving module, and wherein the data can be further utilized as desired. In a preferred embodiment, the electronic device further comprises a solid state memory device wherein the collected data is stored locally on the solid state memory device such that the data can later be downloaded and utilized. Optionally, the solid state memory is selected from the group consisting of Electrically Erasable Read Only Memory (EEPROM), Ferroelectric Random Access Memory (FeRAM), Magnetic Bubble Memory, Flash, Dynamic Random Access Memory, Static Random Access Memory, First In / First Out (FIFO) and Giant MagnetoResistive Random Access Memory (GMRRAM). In a preferred embodiment, the energy source comprises a battery functional at elevated temperatures up to 150°C. Optionally, the battery is selected from the group consisting of lithium metal, lithium ion. and Nickel Metal Hydride (NiH) batteries. A preferred embodiment further comprises an insulation to isolate the material to protect the electronic device from hostile manufacturing or processing environments. Optionally, the isolation material is selected from the group consisting of material with low thermal conductivity, material with low emissivity, and material with low convectivity. Optionally, the isolation material is selected from the group consisting of silica aerogel, carbon aerogel, silica whiskers, vermiculite, stabilized zirconia, clay, and combinations thereof. Optionally, the isolation material is a material with a high resistance to chemical attack or a material with low permeability. In a preferred embodiment, the one or

more sensors, electrical device and energy source operate in a vacuum. In a preferred embodiment, any one of the one or more sensors, electrical device and energy source are hermetically sealed, such that the apparatus is particularly adapted to operation in a vacuum environment. In a preferred embodiment, the one or more sensors, electrical device and energy source are radiation hard, for operation of the apparatus in environments containing radioactive substance. Optionally, the isolation material isolates the one or more sensors, electrical device, and energy source from environmental radiation during operation of the apparatus in an environment containing radioactive substance.

An advantage of the present invention is a device that measures any one or more of the parameters such as temperature, liquid and gas flow rate, distance, particles, humidity, pressure, viscosity, radiation, velocity, density, acceleration, stress/strain, pH and more advanced chemical/material analysis techniques as described in the prior art, in such a way that the sensor is free from wires connecting it to the recorder.

The present invention has particular applicability in monitoring the aforementioned parameters on ~~capital goods~~ semiconductor substrates in microelectronic processing. The present invention has the advantage of monitoring these parameters on the semiconductor substrate remotely, without the need for wires extending from the ~~capital goods~~ semiconductor substrate surface.

Additional advantages and other features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be

learned from the practice of the invention. The objects and advantages of the invention may be realized and obtained as particularly pointed out in the appended claims.

According to the present invention, the foregoing and other advantages are achieved in part by a sensor or sensors attached to the surface, subsurface, or surrounding environment of the ~~capital goods~~ semiconductor substrate and a wire attached from the sensor, to another device attached to the ~~capital goods~~ semiconductor substrate adjacent to the sensor. This device records the data internal to the device for later downloading, or immediate transmitting of this data to a location remote to the ~~capital goods~~ semiconductor substrate and measurement device. This measurement device has particular advantage since it resides completely on the ~~capital goods~~ semiconductor substrate, giving the ~~capital goods~~ semiconductor substrate freedom from wires that otherwise must be attached to a recording device external to the environment of interest. This added benefit allows for non-intrusive installation of the measurement device via the same robotic or automated handling or transport systems using to move the ordinary ~~capital goods~~ semiconductor substrate.

Additional advantages of the present invention will become readily apparent to those having ordinary skill in the art from the following detailed description, wherein the embodiments of the present invention are described, simply by way of illustration of the best mode contemplated for carrying out the present invention. As will be realized, the invention is capable of other and different embodiments, and its several details are capable of modifications in

various obvious respects, all without departing from the present invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

Cancel all paragraphs from page 8, line 18 to page 10, line 13 contained under the title "DESCRIPTION OF THE INVENTION," of the original application. The applicant made the following changes to this section: 1) All instances of the phrase "capital goods" are now replaced with the phrase "semiconductor substrate(s)." 2) Deletion of the phrase starting on Page 8, line 19 "in industries such as farming, mining, construction, non-electrical machinery, transportation equipment (including automobiles), food products, chemicals (including petrochemicals), electrical and electronic equipment, textiles, and utilities.", and replacing it with the phrase "used in the microelectronics industry."

Please insert the following new paragraphs at page 8, line 18, immediately following "DESCRIPTION OF THE INVENTION". The two changes stated above are incorporated in this new text.

The present invention addresses and solves the problem of measuring process parameters on the surface, sub-surface, or surrounding environment of manufactured ~~capital goods~~ semiconductor substrates used in the microelectronics industry. ~~in industries such as farming, mining, construction, non-electrical machinery, transportation equipment (including automobiles), food products,~~

~~chemicals (including petrochemicals), electrical and electronic equipment, textiles, and utilities.~~ These ~~capital goods~~ semiconductor substrates are measured without the requirement for external connections away from the ~~capital goods~~ semiconductor substrate surface or environment, for recording the process data.

In accordance with the present invention, the calibration or measurement device comprises one or more sensors 12, placed on or near ~~capital goods~~ semiconductor substrate 16, connected by wire 10, to an electronic device 14. This electronic device comprises one or more analog-to-digital converters. The digital data can be recorded and saved as a function of time, using one of two options:

- 1) The digital data can be stored as solid state memory, and reside on the ~~capital goods~~ semiconductor substrate. Later, after the recording is complete when the ~~capital goods~~ semiconductor substrate and measurement device are accessible, the data can be downloaded and saved on a computer or other storage device 24.
- 2) The digital data can be transmitted 26 instantaneously using a wireless transmitting module, and recorded using a wireless receiving module 22 and saved on a computer or other storage device 24.

Instantaneous monitoring such as that described in Option 2 is preferred since it allows for real-time data collection. In some applications, wireless transmission is not feasible due to impassible boundaries or materials separating

the transmitter and receiver. In these instances, Option 1 is necessary, where the data is later downloaded for observation.

In an embodiment of the present invention, when the environmental substance to be measured is temperature, the electronic device 13 must remain isolated from the surrounding heat and/or other hostile environments. To prevent heat transfer to the device 13, a thermally insulating material 14 resides between the heat source, and the device 13. In most applications, the only source of heat resides on a heater below the ~~capital goods~~ semiconductor substrate. For applications in which the heat source resides above, or when the device is immersed in the hostile environment, thermal insulation must be provided on all sides of the device. Materials with low thermal conductivities, yet can withstand high temperatures, include, but are not limited to, vermiculite, silica or carbon aerogels, zirconia, stabilized zirconia, and alumina.

Power is provided to the electronic device 13 by a lightweight, compact, and heat resistant battery 20. Lithium and lithium ion batteries meet these requirements, providing high temperature storage capacity up to 500 hours at 150C without any significant voltage discharge.

In an embodiment of the present invention, when the environmental substance to be measured is temperature, the result must not be influenced by conduction along the leads and the sensors. Additionally, the electronic device 13 and battery 20 must reside sufficiently away from the sensors, such that the electronics and battery do not act as a heat reservoir. Figure 4 shows an example of how the sensors 10, electronic device 13, and battery 20 are positioned to

provide maximum separation, and the sensors 10 provide uniformity data across the diameter of the ~~capital goods semiconductor~~ substrate 16.

An advantage of the present invention, as stated in the earlier embodiment, is the non-intrusive handling and positioning of the ~~capital goods semiconductor~~ substrate measuring device, by the same robotics or automated transport used to handle the standard ~~capital goods semiconductor~~ substrate material for manufacturing. Several physical requirements of the measurement device must be met to allow for the robotics to operate without fault in the handling. These physical requirements are mass, balance and dimension. For most robotic systems, the added mass of the battery 20, electronics 13, and sensors 10 should not exceed three times (3X) the weight of the ~~capital goods semiconductor~~ substrate by itself. Secondly, position of the electronic device 13, battery 20, and sensors 10 must also be mass balanced across the ~~capital goods semiconductor~~ substrate 16. Figure 4 provides an example of how the battery 20 with mass m_b counter-balances the electronic device 13 with mass m_e , where $m_b = m_e$. Finally, dimensional constraints exist such that the ~~capital goods semiconductor~~ substrate with the measurement device attached, is similar to, or only slightly larger than the standard ~~capital goods semiconductor~~ substrate dimensions. As the ~~capital goods semiconductor~~ substrate passes between various environments, a minimum clearance must exist to allow for a large enough safety margin for robotic handling inaccuracies, or for other transfer mechanism space limitations.